Student Projects For the New Navy 44 Sail Training Craft

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Vessel Background

- **44-Foot Offshore Sailing Craft for USNA**
  - **1939 Luders Wood Yawl**
  - **1966 Luders Glass Yawl**
  - **1985 McCurdy and Rhodes Sloop**
  - **2003 PYD sloop**

Safety is Paramount – Low Maintenance –10 Crew – Good

Student Research Opportunities at USNA

- Summer Internship
  - ~120 manhours
- Independent Research Project
  - ~ 140 manhours
- Capstone Course
  - ~ 190 manhours
- Trident Project
  - ~ 580 manhours

Total student involvement was about 2000 manhours!

Presentation Overview

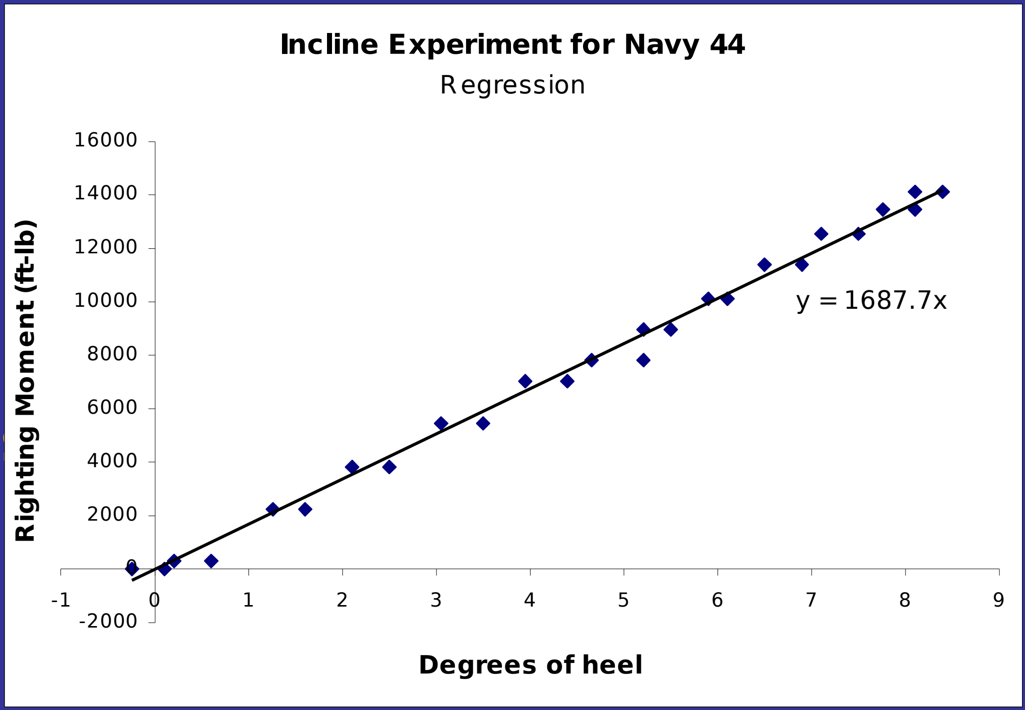
- Nine student projects by eleven students ranging from materials to Computational Fluid Dynamics.
- Student projects both educational and useful in Navy 44 design development

Incline Experiment, Full-Scale Resistance and VPP

- **Researcher: Aaron DeMeyer**
- **Goals: Establish baseline stability and resistance data and develop a VPP tool for future research.**

Full-Scale Incline

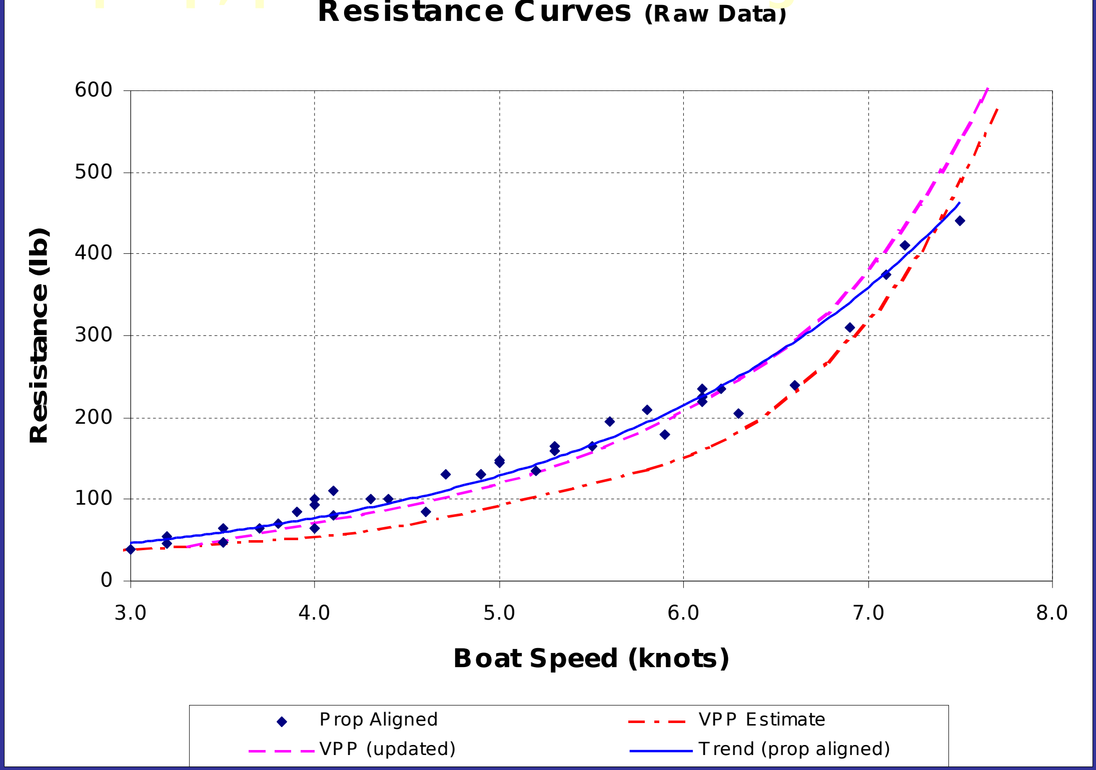
- Incline experiment at full-load (vs IMS) CSNTS condition
  - More stores, equipment, spares
- Two digital inclinometers
- 8500 pounds
- Righting moment decreased 1.2%



Uncorrected (for added weight) Righting Moment

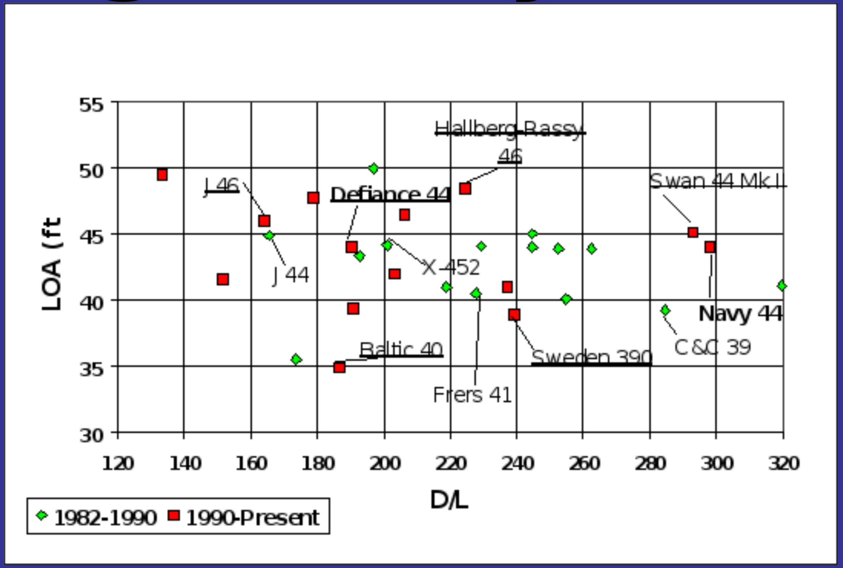
Full-Scale Resistance

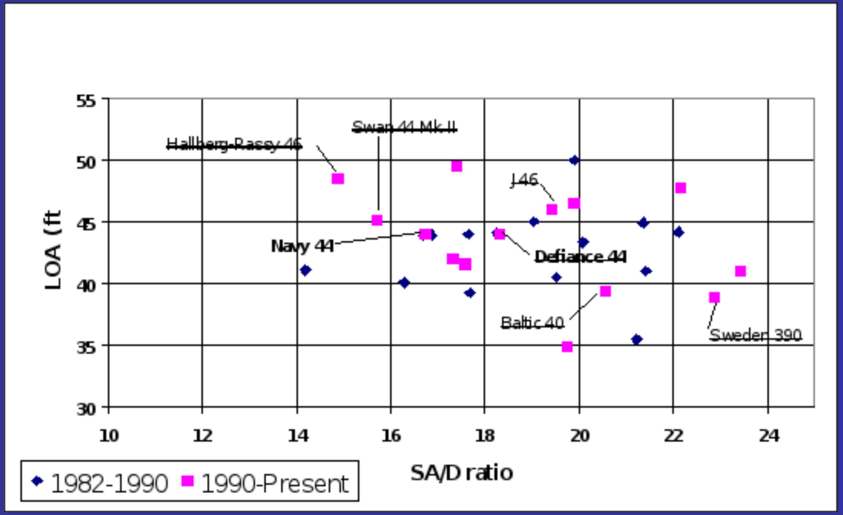
VPP provided by Chris Todter
- **Initial used parametric drag prediction**
- **Updated included strut, shaft, prop, paint and biofouling factors**



Capstone Design Project

- **Researchers: Mark Arvidson, Peter Firenze, Cecily Taylor**
- **Goal: Develop a preliminary design of a new Navy 44 using the same constraints as the current vessel**

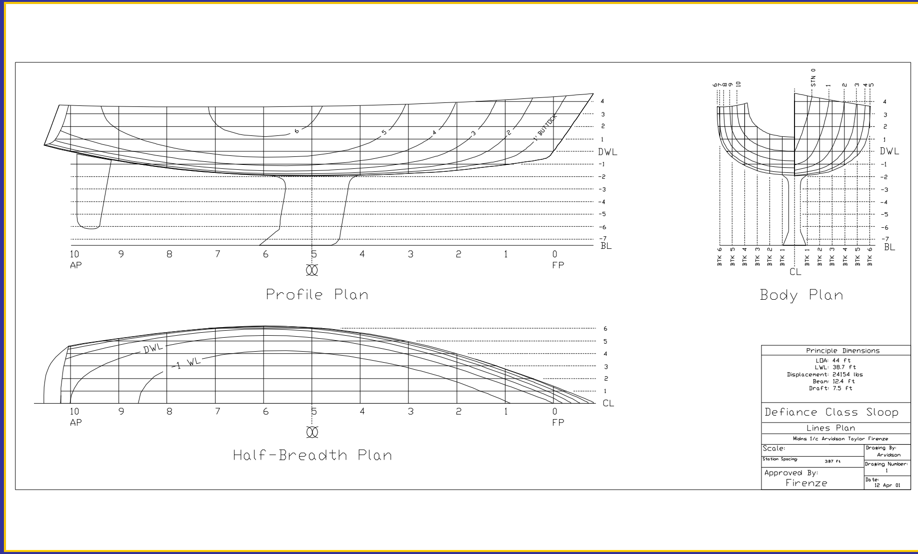




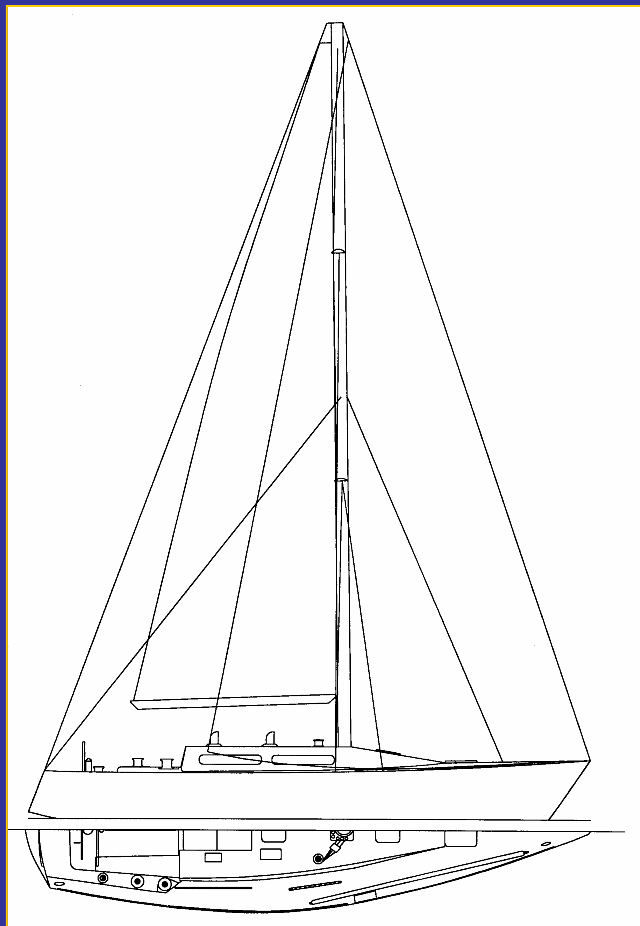
Capstone Design Project

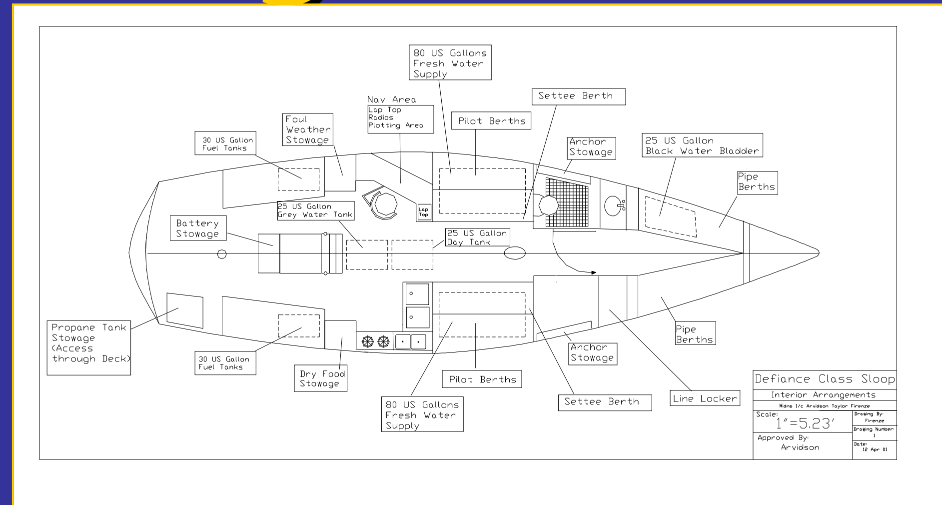
- **All design aspects evaluated and discussed with outside designers**
- **VPP used to improve performance incrementally**

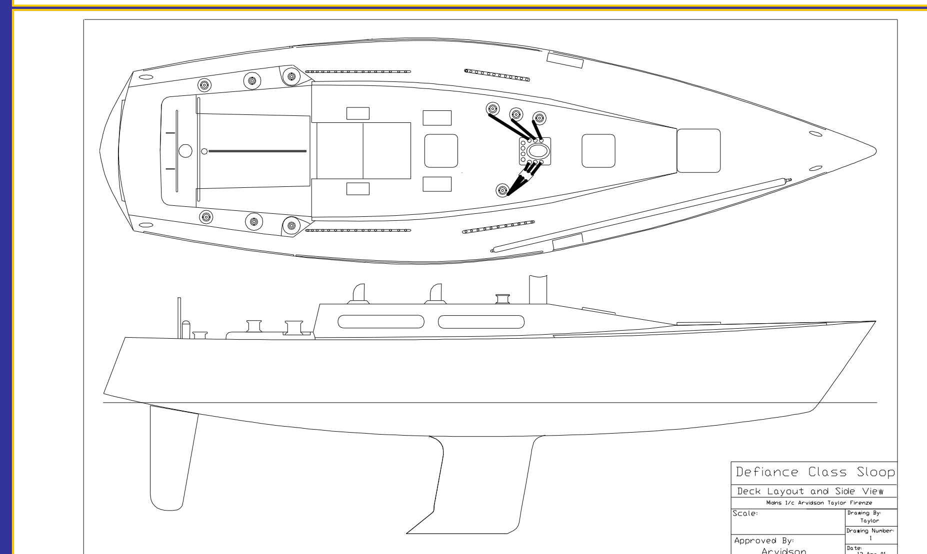
	M&R	"Mk 2" preliminary	Mid 44
LOA (ft)	43.9	44.0	44.0
LWL (ft)	34.2	36.8	38.4
Beam (ft)	12.4	12.4	12.4
Draft (ft)	7.25	7.42	7.42
Disp (lb)	28,600	27,700	24,200
Sail Area (sq ft)	1017	1080	1017
Disp-Length ratio	320.3	249.1	190.8
SA-Disp ratio	17.4	18.8	19.4
LPS (deg)	129	130	143



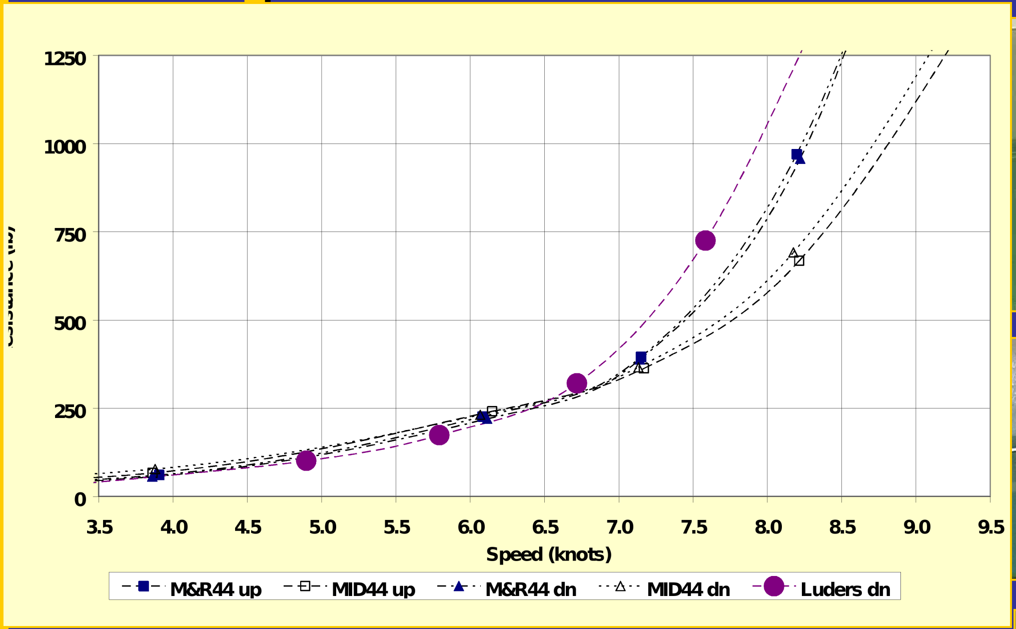
Capstone Design Course







Capstone Design Project

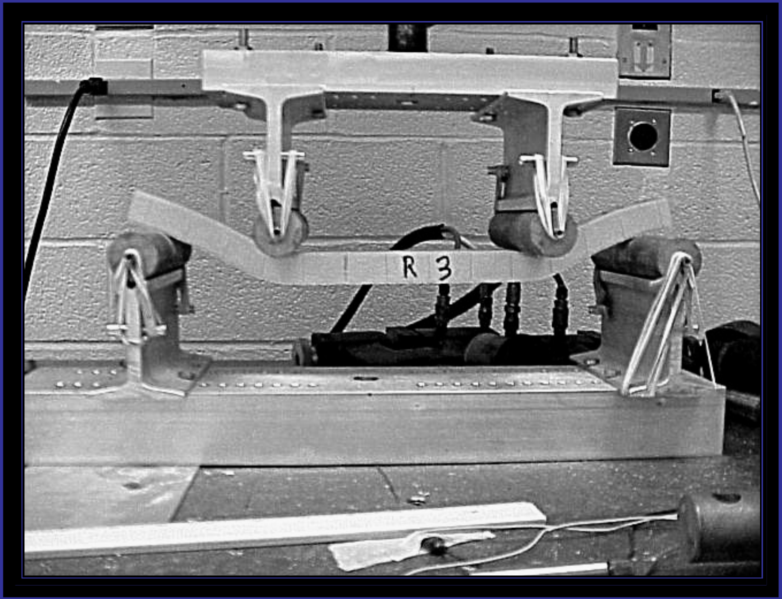


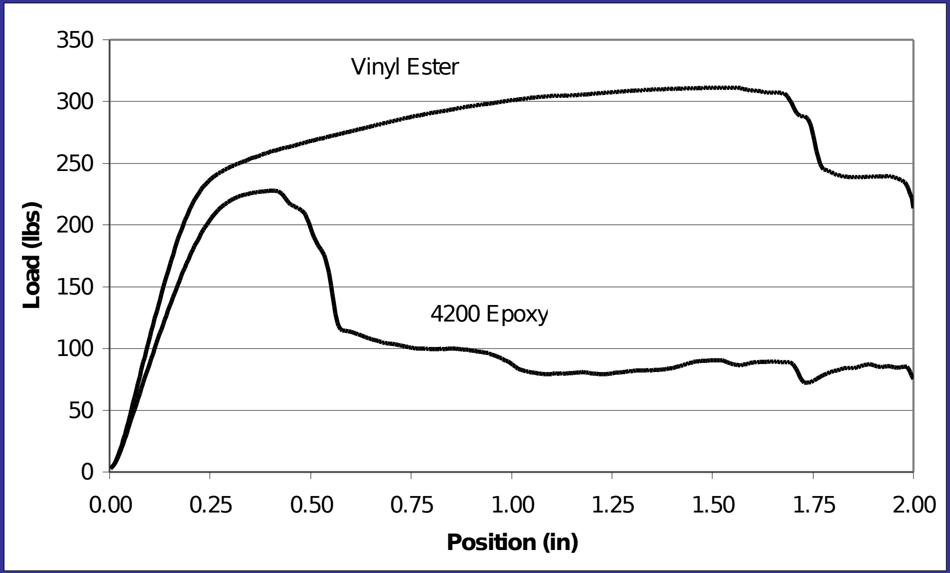
All the designs had roughly the same drag at 6.5 knots boat speed upright. (S/L ratio of 1.1) The biggest differences were seen at higher speeds (winds greater than 10 knots).

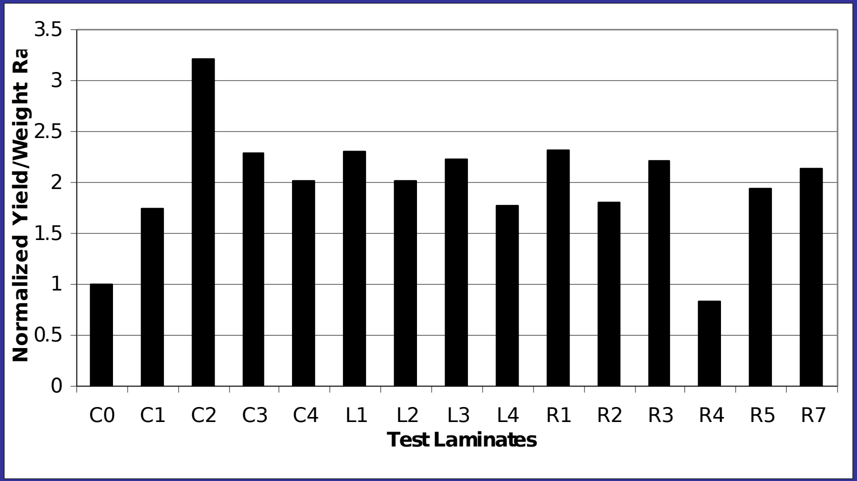
Laminate Upgrade

- **Researcher: Mark Arvidson**
- **Goals: Determine the hull laminate with the best combination of toughness, cost, stiffness and strength to ABS Guide**
- **Approach:**
  - **Laminate analysis programs**
  - **Coupon and panel tests**
  - **Impact tests**

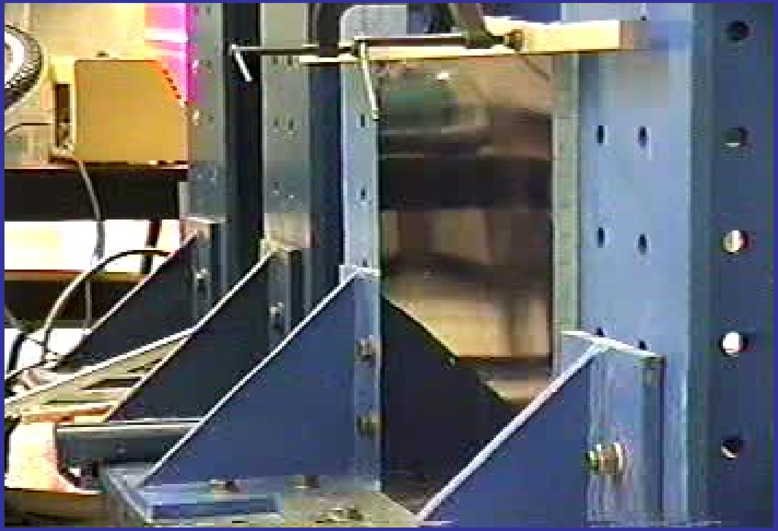
Laminate Selection

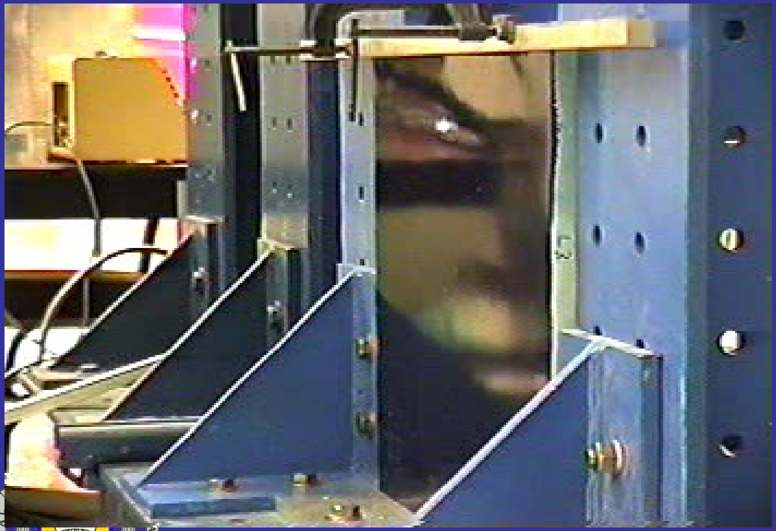


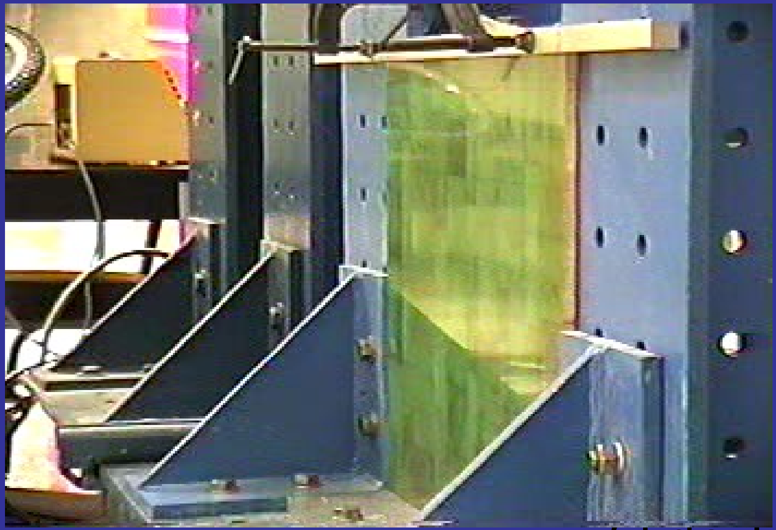




Laminate Selection







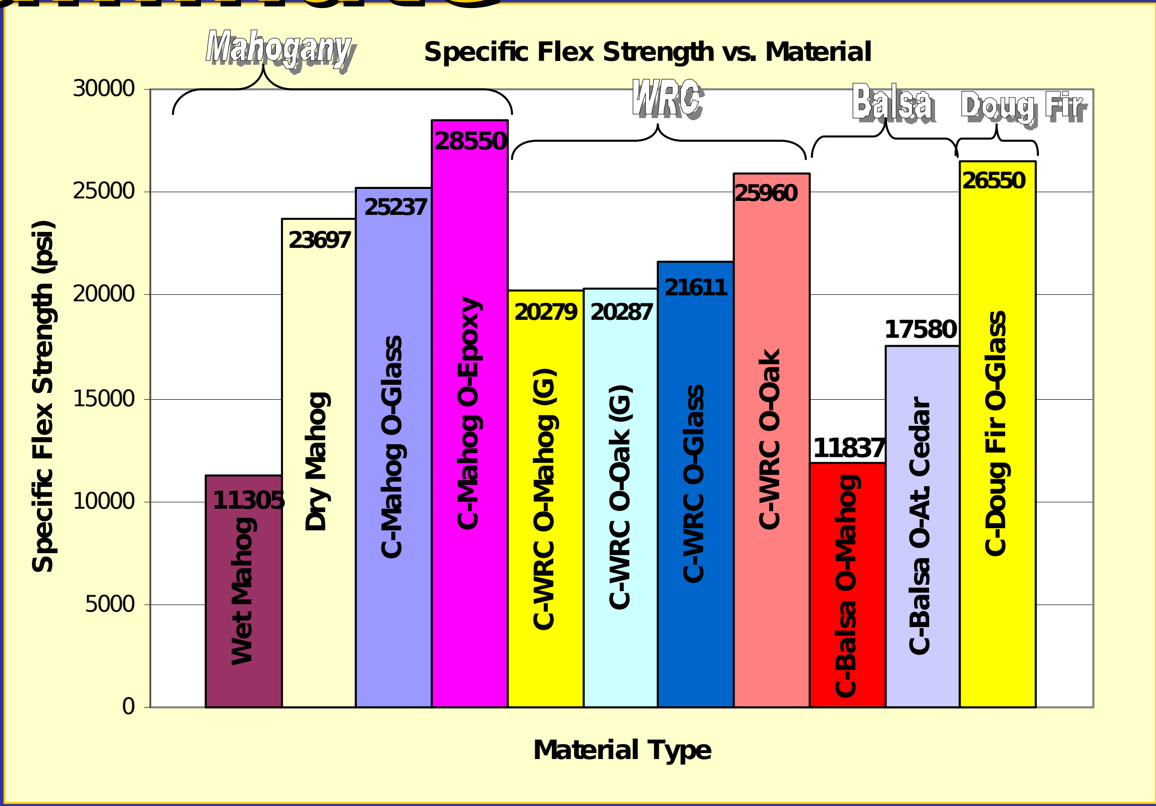
On Water Testing

Alternate Wood Laminate

- Researcher: Kent Simodynes
- Goals: Using ABS, Navy and other analysis methods determine an alternate wood laminate for the Navy 44
- Approach: Analysis, coupon and panel tests

Alternate Wood Laminate

- All three methods agreed with test results for Carvel planking
- Cold-molded were 160-205% stronger than ABS and Navy, 77-120% for CLT/Tsai-Wu



Using the same FOS, wood would be about 400 pounds (2%) h

Keel Section and Shape

- Researcher: Aaron DeMeyer
- Goals: Improve the performance of the new boat through keel planform, section and VCG placement and structural modifications.
- Approach: VPP, tank testing, CFD (with help from Paul Bogataj)
- Solution: J5013 with 5% area reduction and 6” lower VCG yielded an average 8% lower keel drag for an Olympic course at 6, 12, 20 knots wind speed. 0-8 sec/mi improvement.

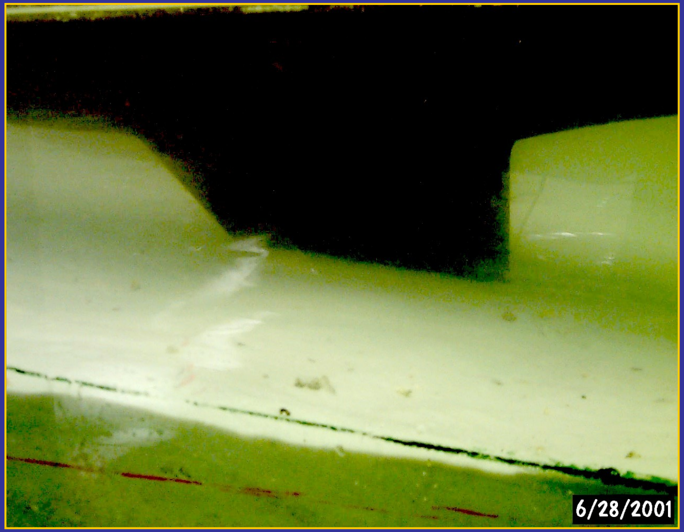
Grounding Comparison

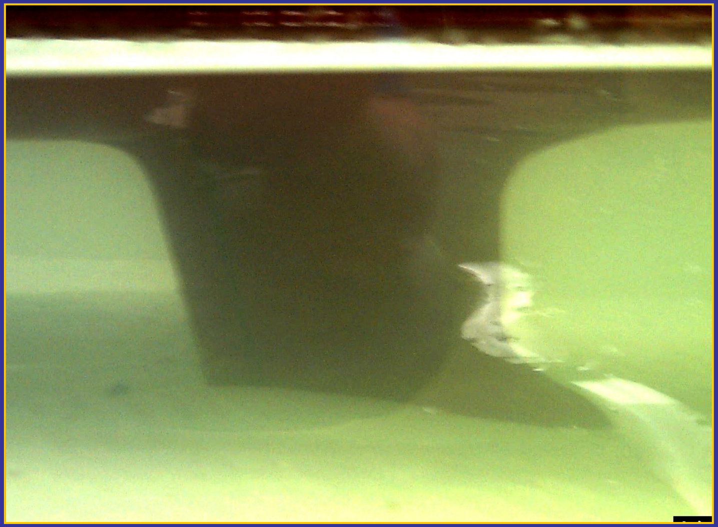
- Researcher: Adam Driessen
- Goals: Determine if IMS-style bulb influences grounding (and ungrounding) characteristics
- Approach: Gravity towed tank testing in Coastal Lab 2-D beach tank

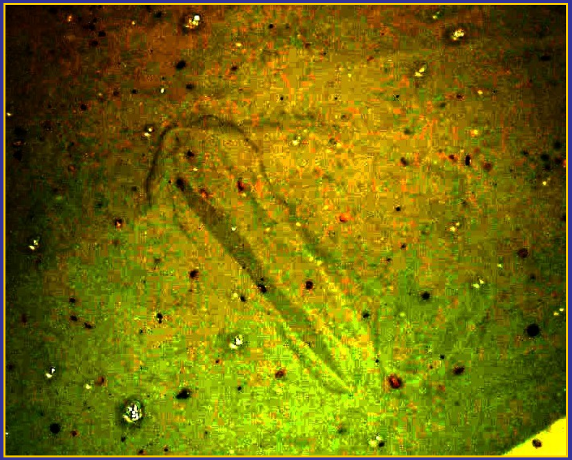
Grounding Comparison

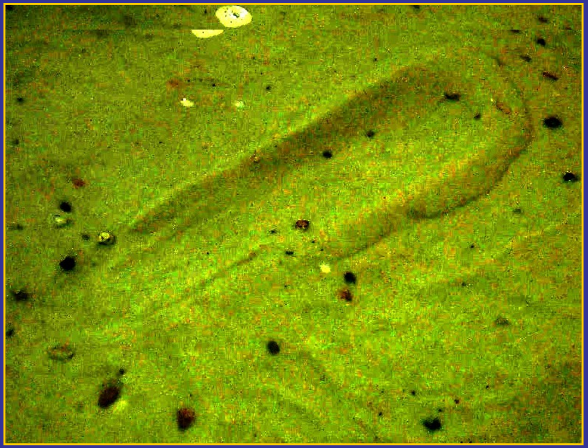
Set up – 2 Hull/Keel Models; Constant Force, Not Constant S

Grounding Comparison









Grounding Comparison

Slope = 1:8

	Velocity (kts)	Avg Force (lbs)	COV
MR44	6.88	1.87	8.6%
MID44	7.43	2.01	8.2%
MR44	3.33	0.92	19.1%
MID44	3.4	0.56	18.0%

Slope = 1:12

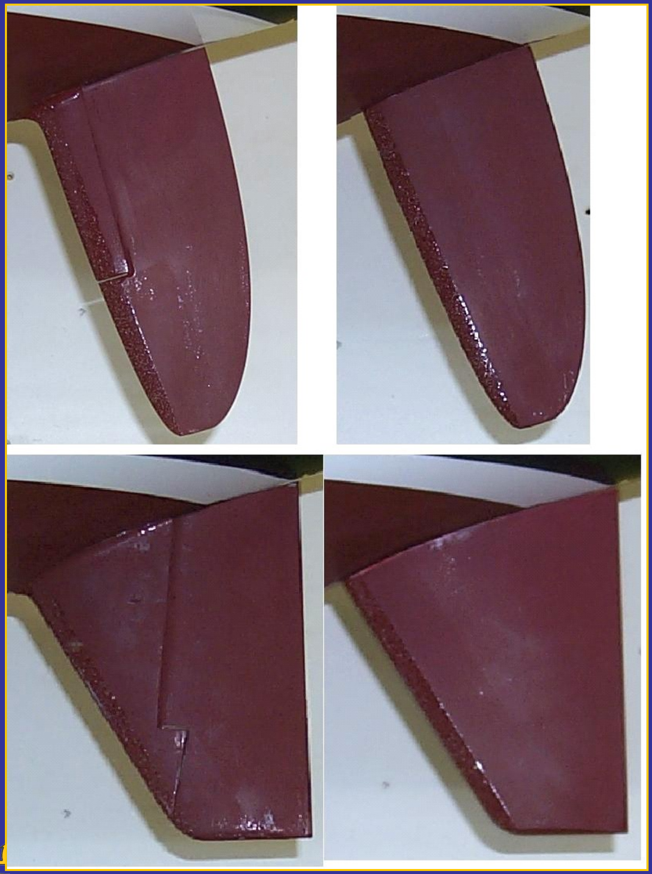
	Velocity (kts)	Avg Force (lbs)	COV
MR44	6.88	2.14	8.9%
MID44	7.43	2.14	16.1%
MR44	3.33	0.95	15.5%
MID44	3.4	0.91	21.5%

Pull off force less for bulb twice, once for fin, once was equa

Rudder Design Comparison

- Researcher: Ted Huebner
- Goals: Determine relative performance in a sail training environment of spade and skeg rudders.
- Approach: Full scale and tank testing (resistance and tactical diameter)

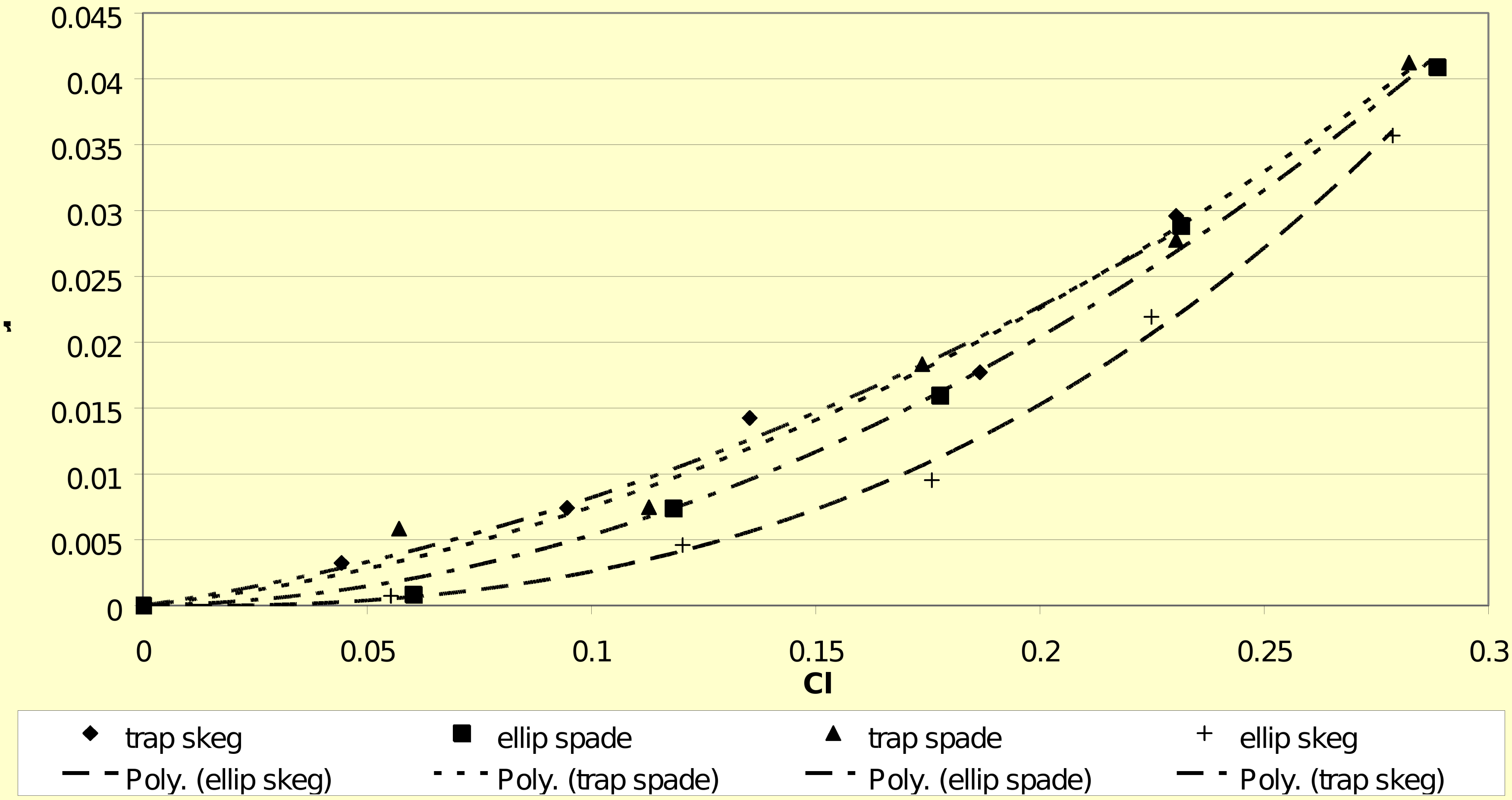
Rudder Design Comaparison



Condition	Radius
	Boat Lengths
Full scale	1.63
Old Hull Existing Rudder	1.39
Old Hull Elliptical Spade	1.24
Old Hull Big Spade	1.22
Old Hull Elliptical Skeg	1.22
New Hull Existing Rudder	1.89
New Hull Elliptical Spade	1.35
New Hull Big Spade	1.22
New Hull Elliptical Skeg	1.22

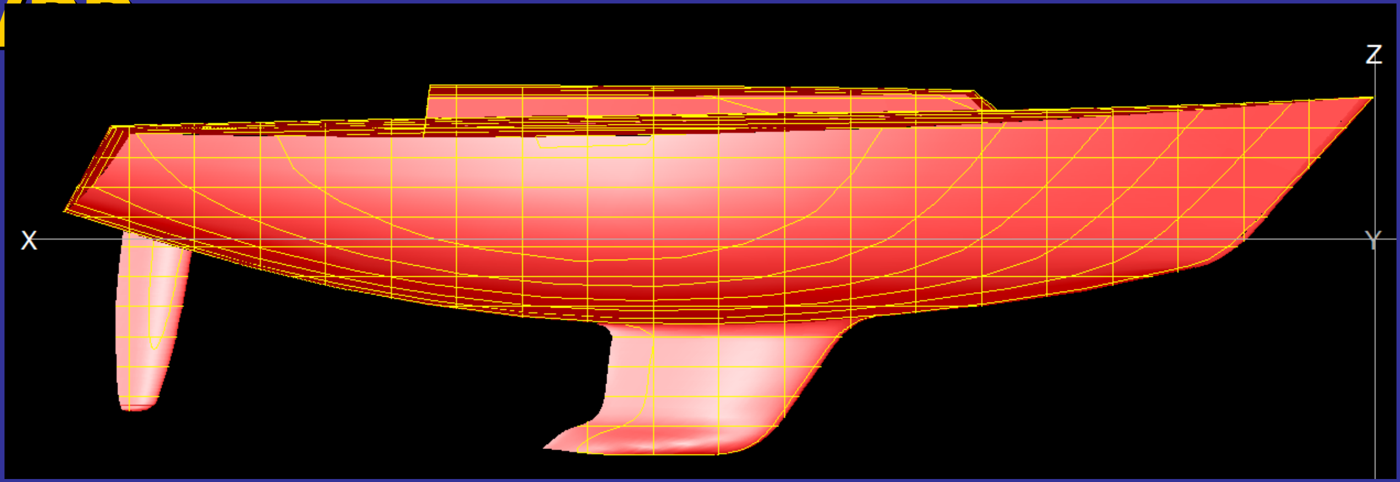
Rudder Design Comparison

Rudder Design Comparison



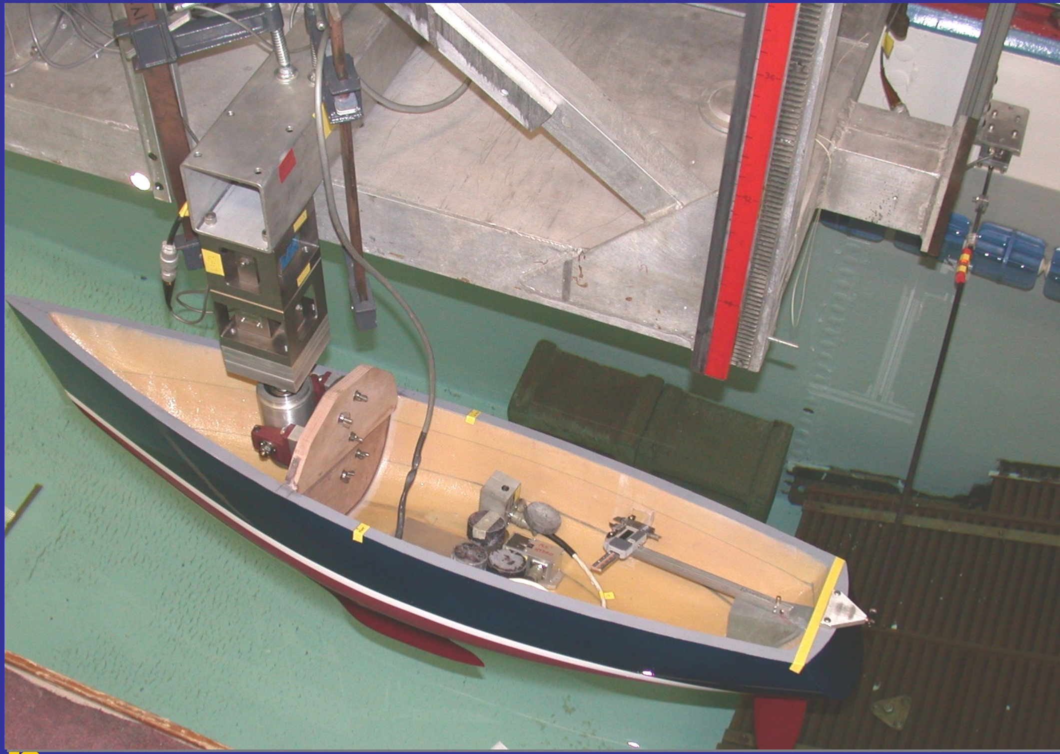
Tank Test/CFD/VPP Study

- **Researcher: Jon Silverberg**
- **Goals: Compare modern prediction methods and improve preliminary design**
- **Approach: CFD, tank testing and VPP**

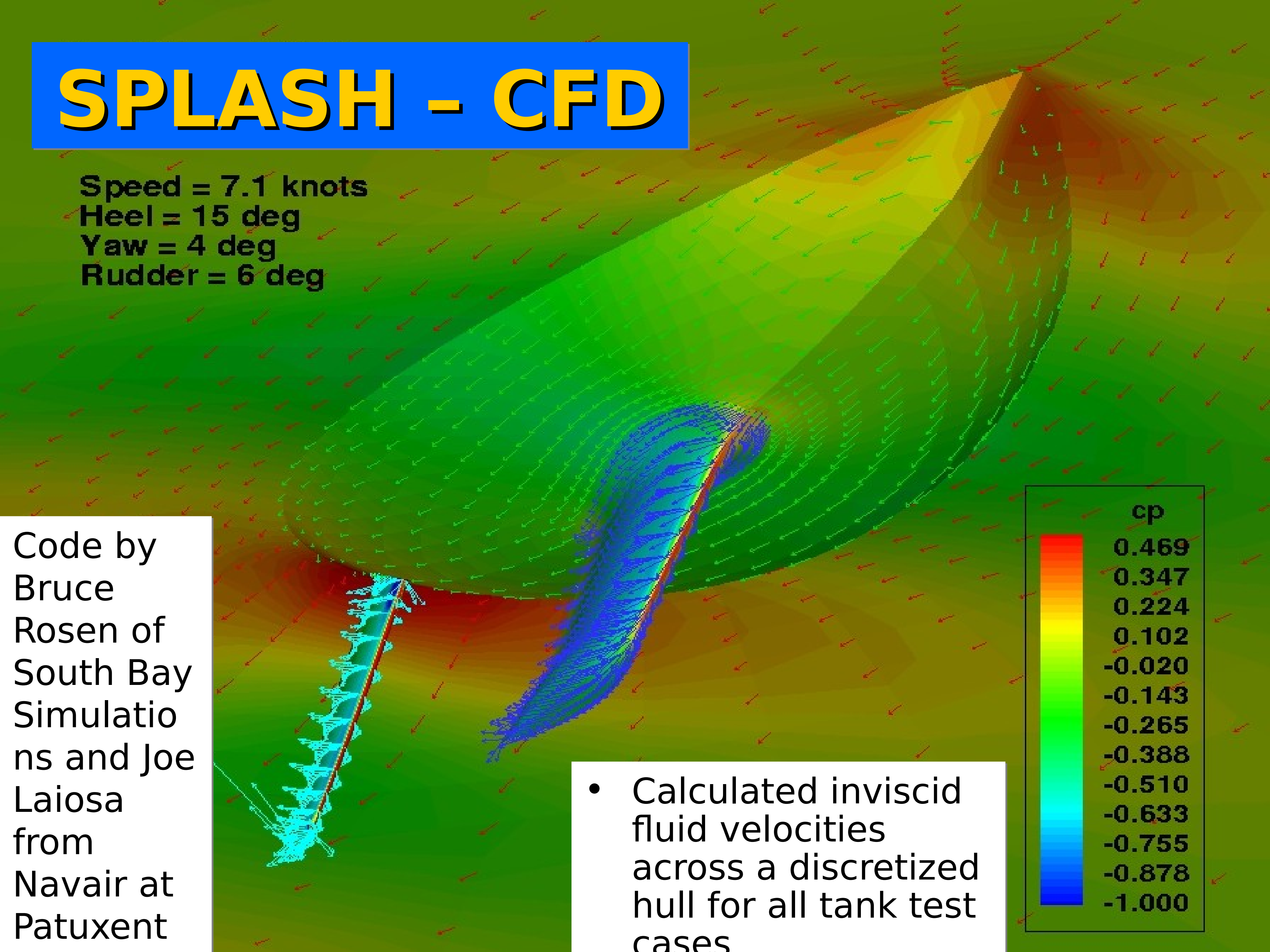


Tank Testing

- New model built to PYD preliminary design
- Data Recorded
  - Drag
  - Lift
  - Yaw Moment
  - Pitch
- Tests included
  - Upright Conditions
  - Sailing Conditions
  - Viscous Corrections
- Performed more than 570 runs



SPLASH – CFD



Code by Bruce Rosen of South Bay Simulations and Joe Laiosa from Navair at Patuxent

- Calculated inviscid fluid velocities across a discretized hull for all tank test cases

PCSail VPP modified for tank and CFD Results

Microsoft Excel - VPP17.XLS

	TWA	TWS	AWA	AWS	TBS	VMG	ABS	SS	Yaw Ang	Rudder Ang	Heel Angle	SailComb	flat/reef	Mastrake	crew
	[deg]	[knots]	[deg]	[knots]	[knots]	[knots]	[knots]	[knots]	[deg]	[deg]	[deg]	[text]	[% / %]	[ft of CE]	[% Width]
Full-scale	40.0	20.0	26.1	24.3	7.31	5.19	7.36	0.70	5.1	3.2	19.8	MJ	1	-1.26	100.00%
Model	40.0	10.6	26.1	12.9	3.9	5.2	3.9	0.4	5.4	3.2	20.5	MJ	0.74	-1.39	100.00%
				Fn	0.360										

Run

Reset

Equation 1: Forces x-direction

Drag	=	Drive
618.386	=	617.836
Difference	-0.549	
% Difference	-0.04%	

Equation 2: Moment x-direction

Rmx +	(Liftk *	Cek) +	(Liftr *	Cer)	=	heelf *	Cesz
-45822.904	1911.297	3.627	-25.097	2.884	=	2102.741	22.201
		-53506.105	+	6860.113	=	-46683.981	
				Difference	-37.989		
				% Difference	-0.04%		

VPP Variables	
Is it bad?	0
Can't Change?	FALSE
1 / Change	6
Boundaries?	FALSE
Is there error?	FALSE
Cgz	-0.818

Equation 3: Forces y-direction

Liftk +	Liftr	=	Lift Sails
1911.297	-25.097	=	1902.988
	1886.200	=	1902.988
	Difference	16.788	
	% Difference	0.44%	

Equation 4: Moment z-direction

Lr *	Cer	=	(LS *	CESx) +	(Ds *	CESy)
-25.097	27.888	=	1902.988	-2.883	617.836	5.256
	-699.897	=	-679.707			
	Difference	0				
	% Difference	-2.88%				

Hydrodynamic Matrix

drag	liftk	liftr	rmmt
618.386	0.000	0.000	0.000
0.000	-6932.502	72.389	53506.105
0.000	1911.297	-25.097	0.000
0.000	0.000	-699.897	0.000

Aerodynamic Answer

sails
617.836
46683.981
1902.988
-679.707

Vectors	lateral direc	vmg	speed	angle
SideSlip	0.535	-0.449	0.699	-40.0
Fmotion	4.729	5.635	7.356	40.0
Sum	5.264	5.186	7.389	45.4

Inverse Hydrodynamic Matrix

0.002	0.000	0.000	0.000
0.000	0.000	0.001	0.000
0.000	0.000	0.000	-0.001
0.000	0.000	0.000	0.000

Solution

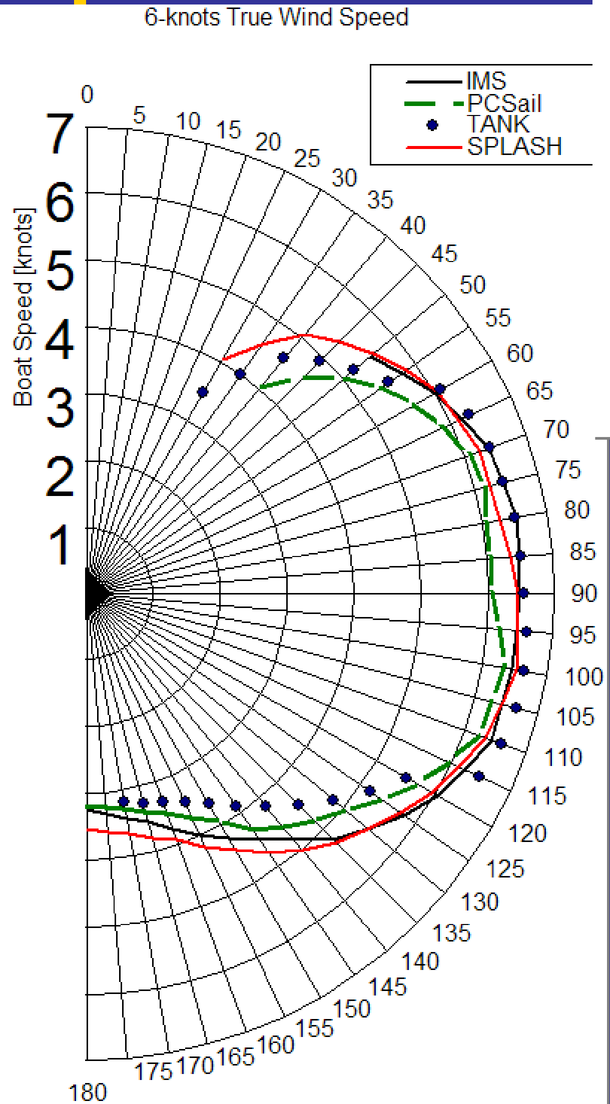
0.999
1.008
0.971
1.002

	% Error	Delta Error	
drag	0.04%	0.04%	
liftk	0.44%	0.44%	
liftr	0.00%	0.00%	
rmmt	0.04%	0.08%	Solution?
	0.44%		TRUE

	Variable	Delta
Speed	3.913	0.000
Heel	20.450	0.000
Yaw	5.424	0.000
Rudder	3.200	0.000
Mastrake	38.607	0.000

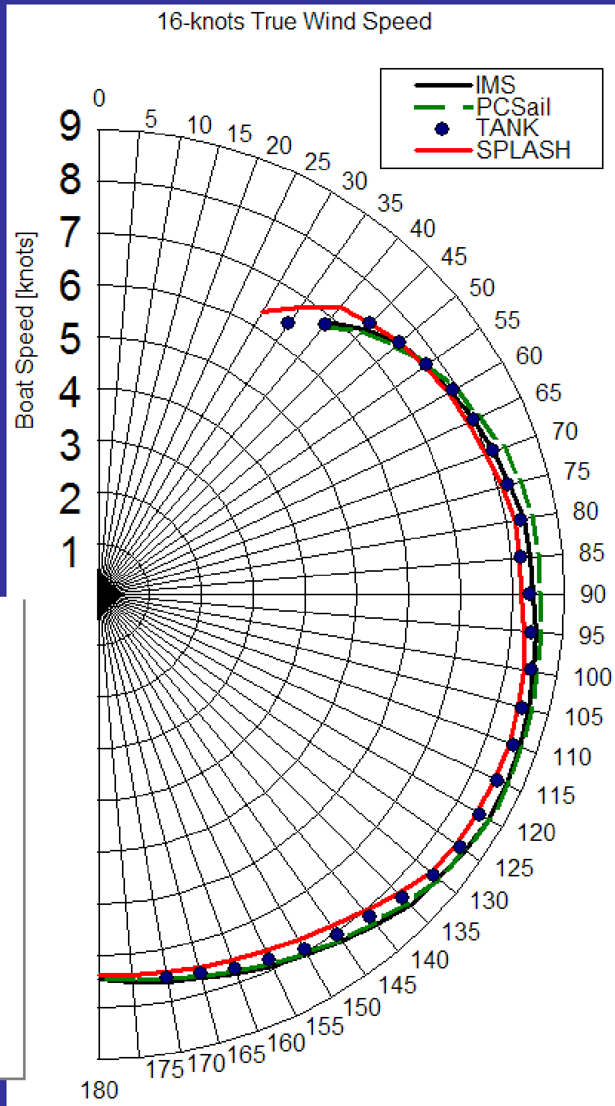
TWA	TWS	AWA	AWS	TBS	Max this var	ABS	Heel	Yaw	Rudder	Flat	Reef	Rake	Heel Moment	Sideforce	Drive
40.000	20.000	26.089	24.339	7.389	5.186	7.356	20.450	5.424	3.200	1.000	0.740	-1.393	46683.981	1902.988	617.836

Performance Predictions



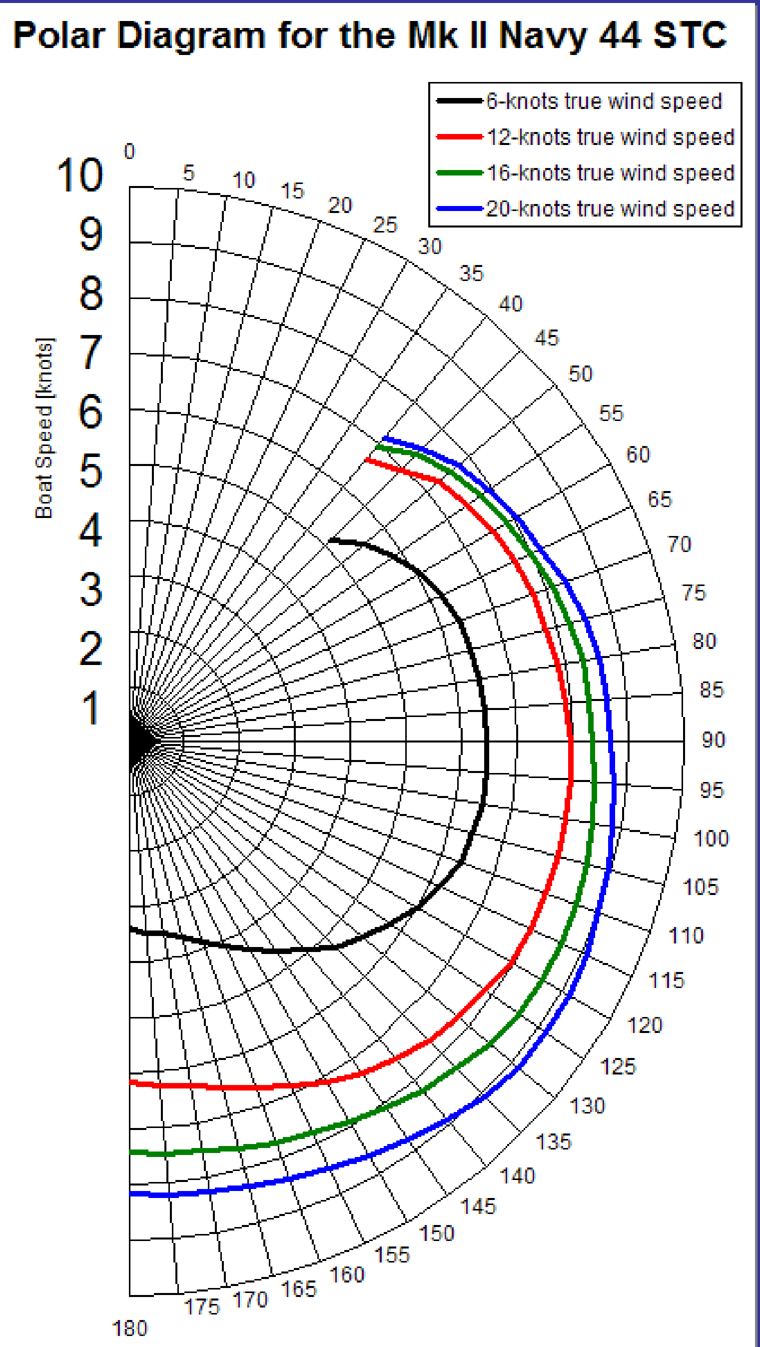
Low wind speeds showed variable results due to simplifications in the aerodynamic model

All other wind speeds showed excellent correlation between all velocity predictions



Final VPP Resul

- Used Tank results and CFD iterations
- VPP and CFD used to look at variations of rig, weight, stability, rudder design
- Suggested changes documented and discussed



Final Results?

- Info from student projects documented and used to develop “consensus” design traits.
- New hull, keel, and rudder shapes.
- New cockpit layout.
- New structural design.
- Students are now submariners, pilots, SWOs and Marines